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Coal Mine Equipment Forecast to 1985

UNITED STATES DEPARTMENT OF THE INTERIOR

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Coal Mine Equipment Forecast to 1985

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UNITED STATES DEPARTMENT OF THE INTERIOR
Thomas S. Kleppe, Secretary

BUREAU OF MINES
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COAL MINE EQUIPMENT FORECAST TO 1985

by

Richard J. Bielicki[1] and David C. Uhrin[2]

ABSTRACT

This Bureau of Mines study estimates the number of major pieces of coal-mining equipment that will be required to produce 950 million tons of marketable coal in 1980 and 1.2 billion tons in 1985. The coal tonnages were projected in the intermediate coal supply scenario of Project Independence Blueprint (PIB). The equipment projections were determined by consideration of historical trends and by evaluation of information from equipment manufacturers and mining companies.

The ability of the manufacturers to meet the projected equipment demands was also determined. It was concluded that equipment supply offers no presently discernible constraint to mining 1.2 billion tons of coal in 1985. A shortfall in projected production for the intervening years, however, is probable owing to anticipated shortages of draglines.

INTRODUCTION

The preparation of Project Independence Blueprint (PIB) in 1974 was one of the first steps carried out by the Federal Government in developing a national energy policy. The PIB study projects in three scenarios the potential supply and demand of U.S. energy sources to 1990 and affords guidelines upon which to rationally develop policy decisions regarding energy utilization.

In the Bureau of Mines present study, the possible number of major pieces of mining equipment that would be required to meet the PIB intermediate coal supply scenario was determined. The study also attempts to project industry's capabilities to meet these equipment needs. Following PIB guidelines, the study determined mining equipment requirements for coal supplies of 950 million tons[3] in 1980 and 1.2 billion tons in 1985, and also adopted the

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[1] Physical scientist (now with Skelly and Loy, Engineers Consultants, Harrisburg, Pa.).
[2] Geologist.
[3] Reference to tons throughout this report refers to short tons.

allocation of these tonnages by coal-producing region and type of mining as outlined by the Interagency Coal Task Force.[4]

In addition to PIB and Interagency Coal Task Force guidelines, this study utilized the Bureau of Mines compilations of coal mine canvas reports for 1971-73, the Minerals Yearbook for 1940-72, and the 1973 Mineral Industry Survey report for bituminous and lignite coal. Also, much valuable information was obtained from mining and equipment manufacturing personnel and from coal mining journals.

The data obtained from these sources were analyzed to determine: (1) The number, producing district location, and average output of the new mines planned and announced by the coal industry; (2) the trends in longwall, shortwall, and other specific types of mining operation; (3) the equipment output differences that exist between the 23 coal-producing districts; (4) the capabilities of the equipment manufacturers to meet the projected demand for new equipment; and (5) additional effects of factors that were considered relevant (for example, production development time). The coal production data were segregated as to producing district, mine output range, and specific type and number of pieces of equipment used. These analyses served as the basis for determining average annual equipment production rates and for forecasting future equipment needs to 1985. Capital, manpower, environmental constraints, or other factors that could preclude the mining of 1.2 billion tons per year by 1985 were not evaluated.

ACKNOWLEDGMENTS

The authors wish to thank the many contributors for their valuable information and insights into the realities associated with mining coal. In particular, our thanks go to Ted Bodimer, Joy Manufacturing Co.; Albert Deurbrouck, Bureau of Mines; John Hall, Harnischfeger Corp.; Tegner Johnson, Marion Shovel Co.; James Linn, Jr., Page Engineering Co.; Eugene Palowitch, Bureau of Mines; and H. C. Schafer, Clark Equipment Co. In addition, our sincerest thanks and appreciation to Lloyd Price of Elmac Corp. and Harold Row of Bucyrus-Erie Co. who devoted much time and effort to the consideration of the data presented.

COAL PRODUCTION--TRENDS AND PROJECTIONS

Since 1940 total coal production has ranged between 400 and 600 million tons per year. This historic trend and the projections to 1985 are shown in figure 1. The projected total tonnage (1.2 billion tons) will require a 7-percent yearly increase in production; surface and underground mine outputs will need to increase by about 8 percent and 4-1/2 percent annually. However, the PIB study shows that 1974 production capacity will be lost through mine closings at 5 percent yearly to 1980 and 3 percent to 1985. Therefore, new capacity[5] will have to provide more than the 7-percent yearly increase in production.

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[4]Interagency Coal Task Force. Report on Project Independence Blueprint. August 1974.

[5]New capacity refers to mines opened after 1974.

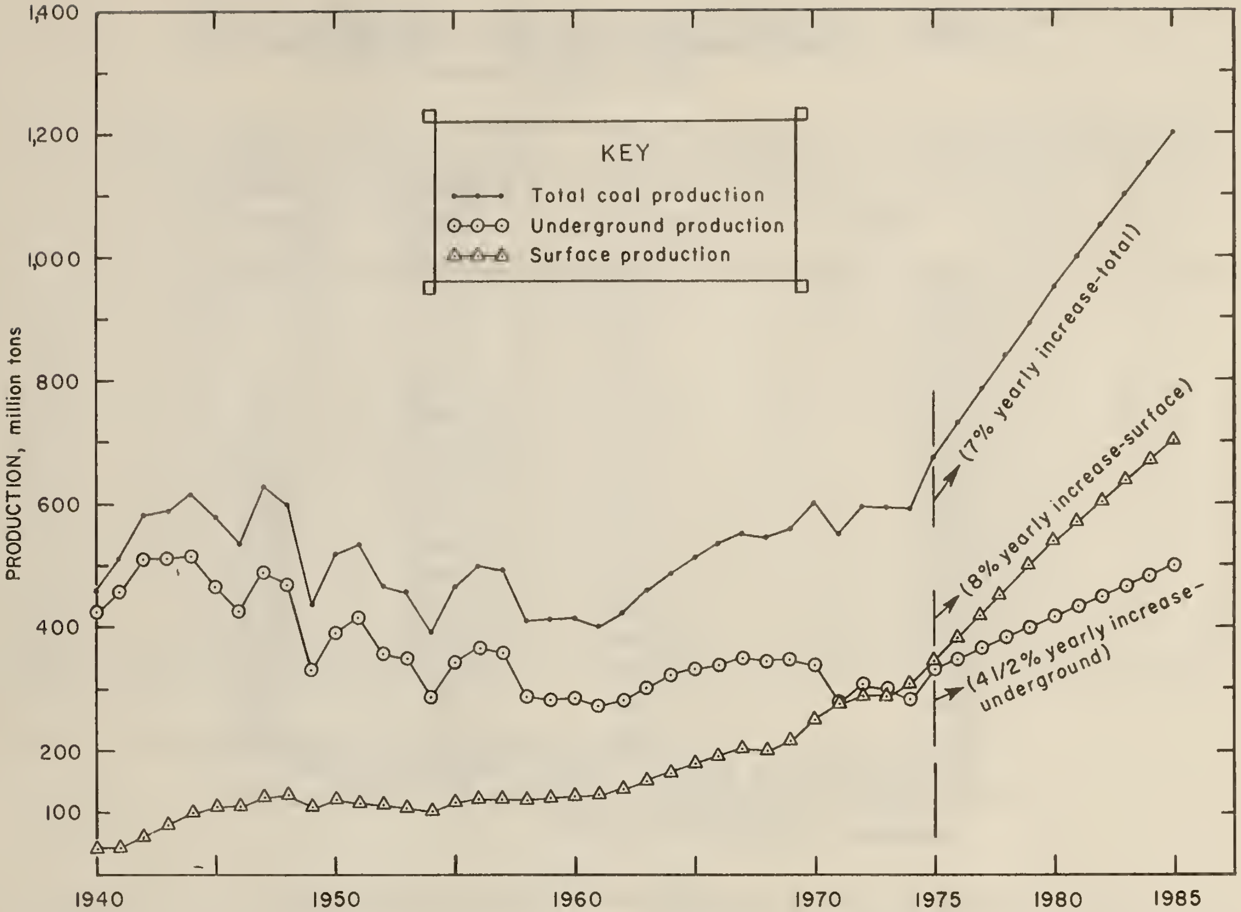

FIGURE 1. - Coal production trends and projections.

The remaining 1974 and new-capacity requirements are outlined in table 1. Of major importance is that a new capacity of 809 million tons per year must be developed by 1985. This is 1.3 times the capacity that existed in 1974 and will constitute 67 percent of the total production in 1985. Table 1 also shows that by 1982 new-capacity output will have exceeded the production that existed in 1974.

TABLE 1. - Total, remaining 1974, and new-capacity coal production, 1971-85

(Million tons)

Year	Total production	Remaining 1974 capacity	New capacity
1971..........	552	-	-
1972..........	595	-	-
1973..........	592	-	-
1974..........	590	[1]620	-
1975..........	675	589	86
1976..........	730	560	170
1977..........	785	532	253
1978..........	840	505	335
1979..........	895	480	415
1980..........	950	456	494
1981..........	1,000	442	558
1982..........	1,050	429	621
1983..........	1,100	416	684
1984..........	1,150	403	747
1985..........	1,200	391	809

[1]The difference between total production and remaining 1974 capacity is due to the coal miners' strike.

Source: 1975-85 data were developed from PIB.

Table 2 lists the production by type of mining projected by PIB and the respective percent of total production. The remaining 1974 and new-capacity tonnages are also shown. Of major importance in table 2 is that 58.5 percent of total production (sum of columns 2 and 6) and 504 of the total 809 million tons of new production (62 percent) are projected to come from surface mines by 1985. These projections are shown in figure 2, where the magnitude of the new capacity is more readily apparent. For surface mining operations, new capacity is shown to exceed remaining 1974 capacity by 1979. These coal production projections shown in table 2 are further separated by producing district and type of mining in table 3. Large increases in strip and underground tonnages are anticipated for every applicable producing district. (A description of producing districts is given in the appendix, based on the Coal Act of 1937.)

TABLE 2. - Coal production for total, remaining 1974, and new capacity by type of mining, 1971-85

(Million tons)

Year	Strip production				Auger production				Underground production			
	Total	Percent of total production	Remaining 1974	New	Total	Percent of total production	Remaining 1974	New	Total	Percent of total production	Remaining 1974	New
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1971.......	259	46.9	-	-	17	3.1	-	-	276	50.0	-	-
1972.......	276	46.3	-	-	16	2.6	-	-	304	51.1	-	-
1973.......	277	46.8	-	-	16	2.7	-	-	299	50.5	-	-
1974.......	295	47.6	[1] 300	-	14	2.5	[1] 14	-	281	49.9	[1] 306	-
1975.......	328	48.6	285	43	17	2.5	13	4	330	48.9	291	39
1976.......	363	49.7	271	92	19	2.5	13	6	349	47.8	276	73
1977.......	398	50.7	257	141	20	2.5	12	8	367	46.8	262	105
1978.......	435	51.8	244	191	21	2.5	11	10	384	45.7	249	135
1979.......	473	52.8	232	241	23	2.5	11	12	400	44.7	237	163
1980.......	512	53.9	220	292	23	2.5	10	13	414	43.6	225	189
1981.......	543	54.3	213	330	25	2.5	10	15	432	43.2	218	214
1982.......	574	54.7	207	367	27	2.5	10	17	449	42.8	211	238
1983.......	607	55.2	201	406	27	2.5	9	18	465	42.3	205	260
1984.......	639	55.6	195	444	29	2.5	9	20	483	41.9	199	284
1985.......	672	56.0	189	483	30	2.5	9	21	498	41.5	193	305

[1]Estimated owing to coal miners' strike.

Source: 1975-85 data were developed from PIB.

TABLE 3. - Total coal production by district and type of mining, 1973, 1980, and 1985

(Thousand tons)

Producing district	1973			1980[1]			1985[1]		
	Strip	Auger	Underground	Strip	Auger	Underground	Strip	Auger	Underground
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	25,061	285	21,100	28,075	530	26,340	33,955	700	30,760
2	7,043	161	26,728	10,365	180	35,120	13,900	265	42,860
3	8,454	431	25,563	11,680	320	34,355	14,370	415	39,120
4	28,527	1,031	16,225	43,805	750	20,235	53,305	1,010	23,740
5	0	0	0	0	0	0	0	0	0
6	120	22	8,711	285	10	11,200	350	10	12,840
7	2,836	493	27,067	6,195	630	39,360	7,355	755	48,095
8	41,848	13,174	99,592	65,745	20,945	153,115	83,575	26,100	190,595
9	31,337	0	22,342	46,740	200	24,995	58,040	245	28,140
10	29,002	0	32,570	43,835	0	38,080	54,430	0	42,870
11	24,465	0	789	34,430	0	1,975	42,755	0	2,220
12	245	0	356	830	0	590	1,030	0	665
13	11,951	105	8,273	23,345	65	13,600	29,670	80	15,775
14	773	0	3	1,105	0	130	1,375	0	150
15	14,528	0	0	44,590	0	0	57,280	0	0
16	0	0	510	0	0	930	0	0	1,250
17	3,026	38	3,584	3,850	0	5,465	5,160	0	7,340
18	11,391	0	0	16,590	0	0	22,535	0	0
19	14,461	0	425	56,095	0	2,305	85,050	0	3,435
20	0	0	5,500	40	0	6,375	55	0	8,060
21	6,906	0	0	23,625	0	0	35,095	0	0
22	10,724	0	1	36,655	0	70	52,725	0	95
23	3,948	0	16	14,120	0	130	20,215	0	185
Total..	276,645	15,739	299,353	512,000	23,630	414,370	672,225	29,580	498,195

[1]Data for 1980 and 1985 are from the Interagency Coal Task Force Report on PIB.

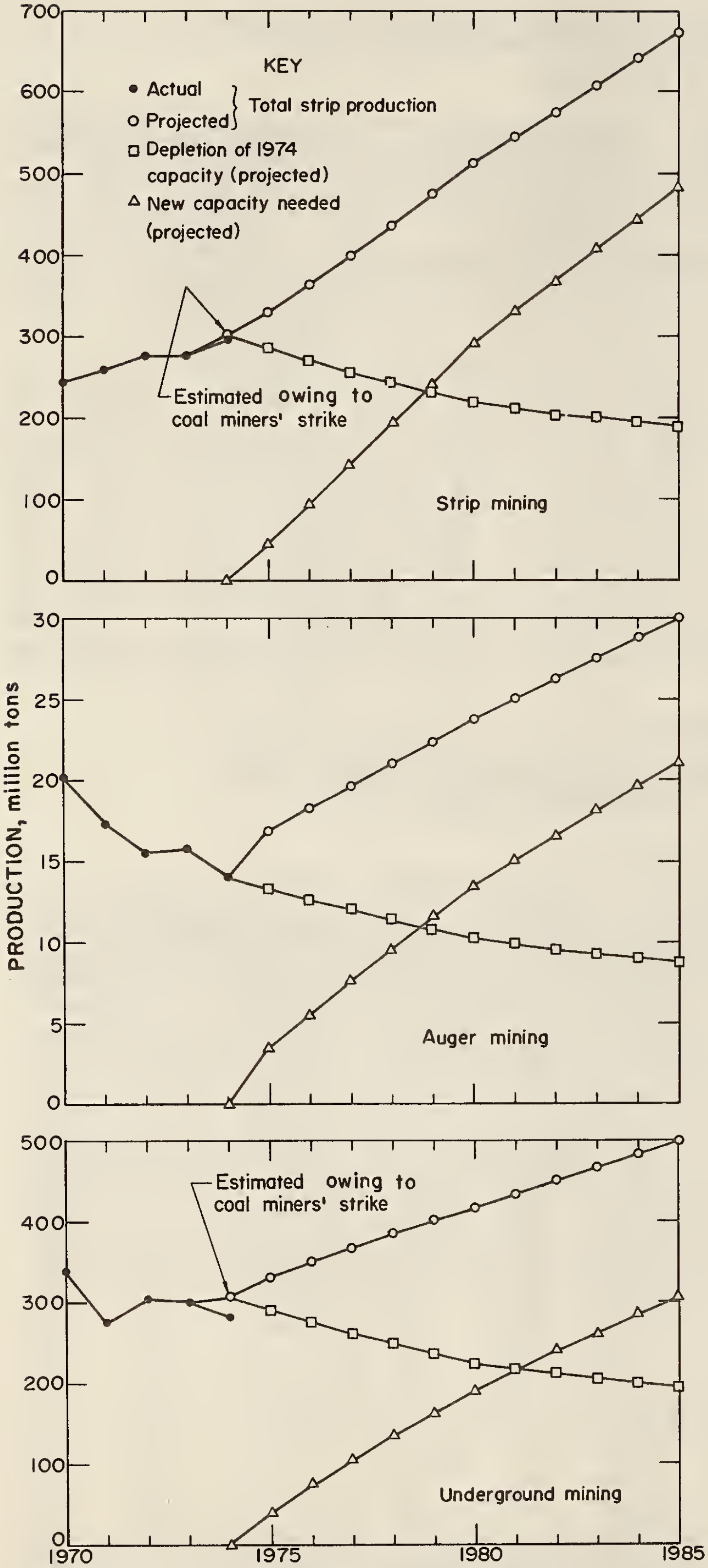

FIGURE 2. - Total, remaining 1974, and new-capacity coal production, by type of mining, to 1985.

In table 4 the 1985 projections are summarized as to remaining 1974 capacity and new-capacity tonnage needed. The number of new mines needed to produce the new-capacity is also shown. This number of mines was determined by evaluation of the latest coal-industry mine development announcements. These mines were categorized by producing district and type of mining, and then average mine outputs for each category were determined. By dividing columns 2, 4, and 6 in table 4 by the respective average mine output, the number of new mines in columns 7, 8, and 9 can be determined. Table 4 also shows large new-capacity increases for almost every mining district. The projections for district 8 in Appalachia, however, lead all others in the magnitude of total production, new production, and number of new mines.

TABLE 4. - Coal production for remaining 1974 and new capacity by type of mining and district (thousand tons), and number of new mines in 1985

District	Strip mining[1]		Underground mining[1]		Auger mining[1]		Number of new mines needed by 1985[2]		
	Remaining 1974 capacity	New capacity	Remaining 1974 capacity	New capacity	Remaining 1974 capacity	New capacity	Strip	Underground	Auger
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	17,155	16,800	13,616	17,144	161	539	25	16	5
2	4,822	9,078	17,247	25,613	90	175	13	24	2
3	5,669	8,701	16,496	22,624	243	172	13	21	2
4	19,527	33,778	10,690	13,050	580	430	34	5	4
5	0	0	0	0	0	0	0	0	0
6	81	269	5,621	7,219	10	0	1	7	0
7	1,940	5,415	17,466	30,629	276	479	11	44	5
8	28,645	54,930	64,262	126,333	7,400	18,700	111	187	201
9	21,452	36,588	14,414	13,726	0	245	13	5	3
10	19,852	34,578	21,017	21,853	0	0	13	8	0
11	16,748	26,007	493	1,727	0	0	9	1	0
12	168	862	230	435	0	0	2	1	0
13	8,180	21,490	5,339	10,436	74	6	21	5	1
14	530	845	2	148	0	0	2	1	0
15	9,944	47,336	0	0	0	0	47	0	0
16	0	0	329	921	0	0	0	2	0
17	2,071	3,089	2,313	5,027	0	0	4	5	0
18	7,798	14,737	0	0	0	0	3	0	0
19	9,899	75,151	272	3,163	0	0	6	3	0
20	0	55	3,548	4,512	0	0	1	2	0
21	4,728	30,367	0	0	0	0	6	0	0
22	7,341	45,384	1	94	0	0	5	1	0
23	2,702	17,513	10	175	0	0	18	1	0
Total	189,252	482,973	193,366	304,829	8,834	20,746	358	339	223

[1] Developed from Interagency Coal Task Force Report on PIB--based on 5-percent production depletion to 1980 and 3 percent to 1985.

[2] Developed in conjunction with coal industry new-mine announcements as reported in the December 1974 Keystone Bulletin and numerous "Developments--news sections" of 1974-75 coal journals.

CONSIDERATION OF RAW COAL TONNAGES

Coal production data are usually reported as marketable coal. Marketable coal is raw coal produced minus the refuse generated in cleaning plants. About 56 percent of the raw coal presently mined goes to cleaning plants, and 25 percent of it ends up as refuse. This refuse, amounting to about 14 percent of the raw coal mined, usually does not appear in production statistics. By 1985 about 70 percent[6] of raw coal will be cleaned, thereby generating 255 million tons of waste. Annual raw coal projections to 1985 are evaluated in table 5.

TABLE 5. - Raw, cleaned, and marketed coal production, 1974-85

(Million tons except as indicated)

Year	Raw coal mined	Raw coal cleaned, percent	Coal refuse	Coal marketed[1]
1974.......	686	56	96	590
1975.......	794	60	119	675
1976.......	861	61	131	730
1977.......	928	62	143	785
1978.......	997	63	157	840
1979.......	1,064	64	169	895
1980.......	1,133	65	183	950
1981.......	1,197	66	197	1,000
1982.......	1,260	67	210	1,050
1983.......	1,325	68	225	1,100
1984.......	1,390	69	240	1,150
1985.......	1,455	70	255	1,200

[1]From table 1.

Because of the large tonnages involved, how raw coal production affects mining equipment needs was considered worthy of investigation, but analysis of the available data indicated that raw coal production had little effect on equipment projections. For example, when the output capacity of a continuous miner based on raw coal was compared with that based on marketable coal, projections of the number of pieces of equipment needed varied only 0.4 percent annually. Therefore, production figures throughout this report are marketable coal tonnages.

DETERMINING EQUIPMENT PROJECTIONS

In deriving the following data, different procedures were utilized for underground and strip mining projections. This was due to the differing nature of the operations, the equipment used, and the information available. It was assumed that the new equipment needed would be made available at the

[6]Mainly due to environmental considerations relating to sulfur reduction of feed coal.

beginning of the year and that wornout and discarded equipment would be lost at the end of the year. In this regard an 11-year projection period was established. Generally, a slightly different procedure or methodology was warranted for data reporting for each type of equipment, and the procedure is discussed in the respective sections. After equipment needs had been considered, the potential of the equipment manufacturers to meet these needs was determined.[7] Other considerations that affect equipment supply were then discussed in summing up the sections.

Auger mining was not evaluated for this study. Due to the small amount of mining projected to be done by augering, it was assumed that equipment supply would be adequate. The tonnage projected to come from this type of mining is included in the tables in order to maintain continuity with total tonnage projections.

When this study projects equipment shortages and suggests alternative methods to recover the potential lost production, it does so in the context of maintaining continuity with PIB tonnage projections. Therefore, whether or not 1.2 billion tons of coal can be marketed by 1985 is not in contention here--the equipment needed to produce this tonnage is the overriding consideration.

This study is concerned mainly with major mining equipment needs and potential equipment supply. It does not evaluate the capital, men, time, and other needs of the mining industry, other than equipment, to meet the projections considered. This study also makes no allowances in the projections for production losses due to coal miners' strikes, although it is recognized that they probably will occur.

UNDERGROUND MINING EQUIPMENT

For underground equipment projections, the number and average output of new and remaining 1974 mines to 1985 were the first determinations. Past trends in underground mining were then reviewed, and viewpoints of the respective equipment manufacturers, mining companies, and Government analysts were considered in developing future trends.

In the tables developed for reporting underground equipment statistics, prior trends for an applicable period are included with the projections. These projections include one or more of the following: (1) Number of machines in use, (2) average output per machine, (3) number of machines needed for new mines, (4) number of spare machines needed, (5) number needed for replacement of wornout machines, and (6) total number of machines needed. A recapitulation of the total equipment needed by producing district for new-capacity mines is given at the end of the underground mining equipment section.

A 4- to 4-1/2-year development time is often required for a new underground mine to reach a designed total output of 900,000 tons per year

[7]Coal Mining and Processing. Coal '75: The Manufacturers' Perspective. V. 12, No. 1, January 1975, pp. 44-49, 72.

(assuming a 6-month development time per continuous miner). From the time the first continuous miner goes underground until the ninth one reaches full output (assuming 100,000 tons per year per continuous miner), the production of the mine could resemble the following:

Year	Number of continuous miners in use	Production (tons)
1.........	2	150,000
2.........	4	350,000
3.........	6	550,000
4.........	8	750,000
5.........	9	900,000

However, a countereffect to production losses due to development time could be achieved by increasing production in existing mines. Determining the ultimate quantitative effect of both of these factors is difficult; therefore, production losses due to development time are not considered in the following

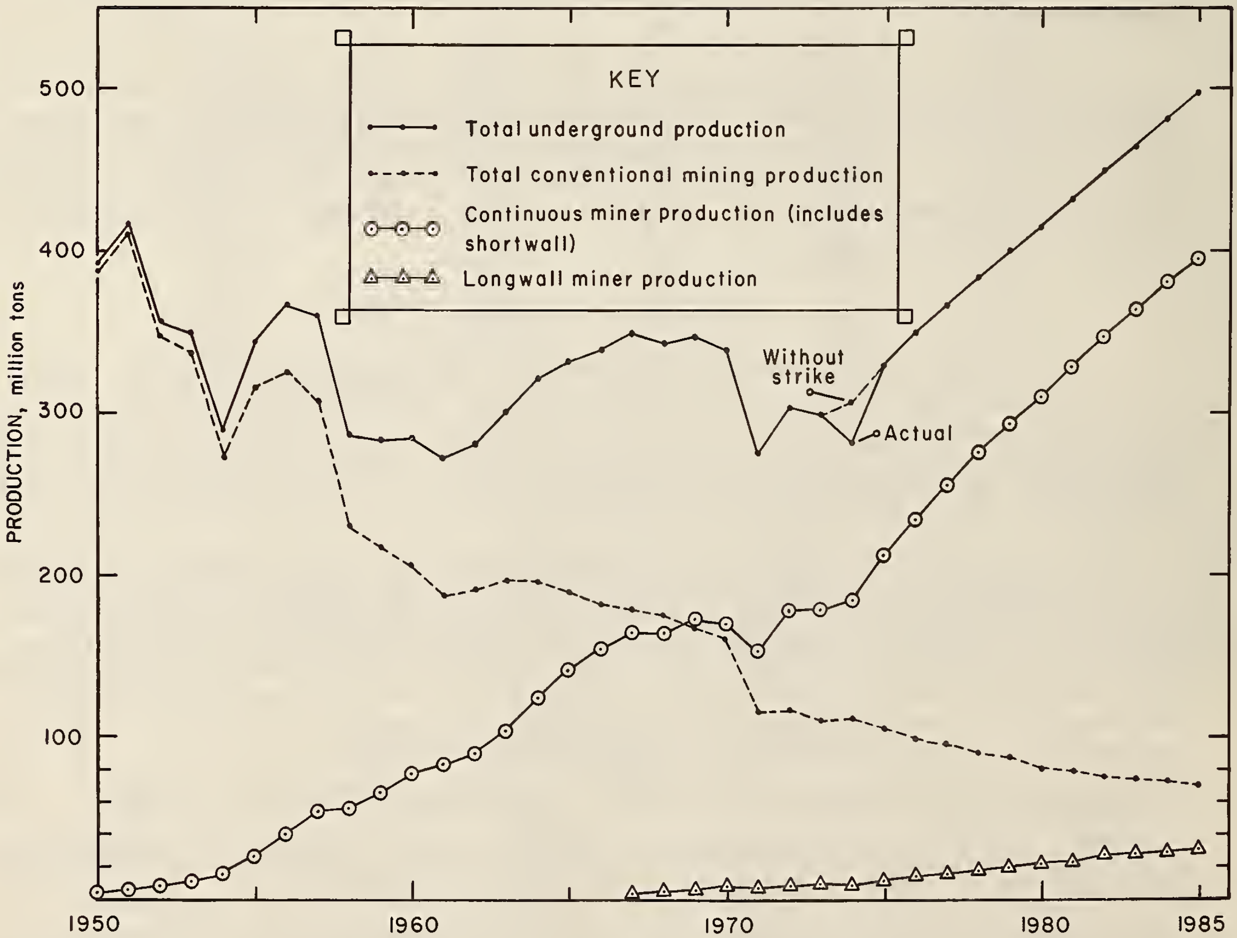

FIGURE 3. - Methods of underground mining to 1985.

projections. For our purposes it is sufficient to say that the problem will exist.

In underground mining operations, the trend is toward continuous miners and longwall miner sections and away from conventional mining, as shown in figure 3. Continuous miners are projected to produce about 80 percent of total underground tonnage by 1985. Conventional machines will provide only 14 percent, and longwall mining will have increased to only 6 percent of total underground production by 1985.

The average output and number of new and remaining 1974 underground mines are reported in columns 3-6, table 6. These data were developed from the same information used in tables 3 and 4, including the new-mine announcements of the coal industry. The average output of remaining 1974-capacity mines will continue to be about 176,000 tons per year, while new mines are projected to average 900,000 tons per year. The total number of underground mines will continue to decrease through 1985 even though total underground tonnage increases by about 63 percent. This is because the average new mine is projected to produce about five times as much coal as the average mine that existed in 1974.

TABLE 6. - Number and average output of new and remaining 1974 underground mines, 1970-85

Year	Underground production,[1] thousand tons	Total number of mines	Number of remaining 1974 mines	Estimated number of new mines needed	Average output of remaining 1974 mines, thousand tons	Average output of new mines, thousand tons
	(1)	(2)	(3)	(4)	(5)	(6)
1970..	338,788	2,939	NAP	NAp	NAp	NAp
1971..	275,888	2,268	NAp	NAp	NAp	NAp
1972..	304,103	1,996	NAp	NAp	NAp	NAp
1973..	299,353	1,737	NAp	NAp	NAp	NAp
1974..	[2]306,000	[3]1,737	NAp	NAp	NAp	NAp
1975..	330,075	1,694	1,650	44	176	900
1976..	348,940	1,649	1,567	82	176	900
1977..	367,380	1,606	1,489	117	176	900
1978..	383,880	1,565	1,415	150	176	900
1979..	400,065	1,526	1,344	182	176	900
1980..	414,370	1,487	1,277	210	176	900
1981..	432,000	1,477	1,239	238	176	900
1982..	449,400	1,467	1,202	265	176	900
1983..	465,300	1,455	1,166	289	176	900
1984..	482,600	1,446	1,131	315	176	900
1985..	498,195	1,436	1,097	339	176	900

NAp--Not applicable.
[1]Developed from table 2.
[2]Estimated owing to coal miners' strike.
[3]Estimated because data were not available.

Continuous Miners

The trends and projections of the need for continuous miners are shown in table 7. About 5,705 new continuous miners will have to be shipped to domestic markets in 1975-85 (column 7), 3,795 for new mine operations and 1,910 for replacement.

TABLE 7. - Continuous-miner statistics, 1950-85

Year	Continuous miner production, thousand tons	Percent of underground production	Number in use	Average output per miner, thousand tons	Number needed for new capacity (including spares)	Number needed for replacement	Total needed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1950..	4,850	1.2	90	53.9	NAp	NAp	NAp
1955..	27,460	8.0	385	71.3	NAp	NAp	NAp
1960..	77,928	27.4	879	88.7	NAp	NAp	NAp
1965..	141,938	42.7	1,218	116.5	NAp	NAp	NAp
1970..	169,897	50.1	1,566	108.5	NAp	NAp	NAp
1971..	152,943	55.4	1,781	85.9	NAp	NAp	NAp
1972..	178,375	58.7	1,849	96.5	NAp	NAp	NAp
1973..	178,600	59.7	1,866	95.7	NAp	NAp	NAp
1974..	[1] 185,000	[2] 60.5	[2] 1,976	[2] 93.7	NAp	NAp	NAp
1975..	211,975	64.2	2,200	96.4	360	110	470
1976..	233,915	67.0	2,360	99.1	360	110	470
1977..	255,235	69.5	2,552	100.0	360	110	470
1978..	274,553	71.5	2,746	100.0	360	110	470
1979..	293,374	73.3	2,934	100.0	360	110	470
1980..	310,112	74.9	3,101	100.0	360	110	470
1981..	328,616	76.1	3,286	100.0	327	250	577
1982..	346,690	77.1	3,469	100.0	327	250	577
1983..	363,321	78.1	3,633	100.0	327	250	577
1984..	380,489	78.8	3,805	100.0	327	250	577
1985..	396,940	79.7	3,969	100.0	327	250	577
Total	NAp	NAp	NAp	NAp	3,795	1,910	5,705

NAp--Not applicable.
[1]Estimated owing to coal miners' strike.
[2]Estimated because data were not available.

Methodology Used

About 60 percent of underground production in 1974 was from continuous miners, and this is expected to increase to about 80 percent by 1985. The continuous-miner production (column 1)[8] can be derived by multiplying the

[8]In each section, references to columns of a table are to the table accompanying that section; if a table in another section is cited, such as the reference to table 6 later in this sentence, both the column and table numbers are given.

percent of underground production by continuous miner (column 2) times the total underground production (column 1, table 6). Production can also be determined by the summation of continuous-miner production from remaining 1974 capacity plus the amount of new capacity that will be produced by continuous miners. The continuous-miner production from remaining 1974 capacity to 1985 was projected to remain at 60.5 percent. For new-capacity production it was assumed that 92 percent would come from continuous miners. The remaining 8 percent would come from longwall mining with no new mines expected to use conventional techniques. (It is recognized that some new mining operations will probably utilize conventional equipment. The production from these is expected to be minimal, however, in comparison to the total new underground production that has been projected. Therefore, for purposes of simplicity, all new underground production is assumed to come from continuous-miner or longwall sections.)

The average output per continuous miner (column 4) was assumed to continue at the approximate historical average of 100,000 tons per year. If this does not hold and the output increases, fewer continuous miners would be needed to obtain the respective tonnages. An alternative method of obtaining this output figure was also employed in which the continuous-miner output for each producing district was determined from coal mine canvas reports for 1971-73. The output value was developed by consideration of only those existing mines that were within the size range of the new mines announced for that district by the mining industry. These outputs ranged from about 70,000 to 170,000 tons per year. In this regard a weighted average output of about 100,000 tons per year was determined. This is the same as the average output per miner that is projected in column 4 for the period 1977-85.

The number of miners in use in any year (column 3) is derived simply by dividing column 1 by column 4. This number can also be determined by consideration of the number in use during the previous year, the approximate number that wear out and are discarded during the year, and the total number of new miners projected as needed during the year.

The number needed for new capacity (column 5) was projected by consideration of individual producing-district needs. To calculate these district needs, the new capacity projected for the district (column 4, table 4) was divided by the district continuous-miner output value, which was previously derived. Where district information was suspect, scarce, or not available, the nationwide weighted average of 100,000 tons per year was used. These individual producing-district needs were then totaled, and to this total a spare miner for every four new-capacity miners was added. Since each continuous miner is rebuilt after producing about 200,000 tons of coal, a spare machine must be available to enable production to continue at the desired level.[9]

The number needed for replacement (column 6) refers to those wornout and discarded machines that must be replaced if the remaining 1974-capacity

[9] Bodimer, T., and L. Price. Private Communication, 1975. Available upon request from Ted Bodimer, Joy Manufacturing Co., or Lloyd Price, Elmac Corp.

tonnages (column 3, table 4) are to be maintained. The average useful lifetime of a continuous miner is about 10 years. It can be assumed, therefore, that the 5 percent and 3 percent yearly mine closings discussed previously will account for 50 percent and 30 percent of the discarded miners. Therefore, the number that must be replaced to maintain the remaining 1974 tonnage becomes, respectively, 50 percent and 70 percent of the total number discarded. Many mining companies, however, tend to try to prolong the useful life of continuous miners, as well as other equipment, and the replacement factor may not hold on a yearly basis.

The number of miners needed for the periods 1975-80 and 1981-85 were totaled, and the period average for the respective years is shown in columns 5, 6, and 7. This is done to emphasize that the yearly totals should be given less consideration than the total projections.

Other Considerations

Column 5 shows a greater number of new continuous miners being needed initially than in the later part of the projection period. This is because, in PIB, new underground capacity was projected at a yearly high of 39 million tons in 1975, decreasing to 21 million tons in 1985. (This can be calculated from column 12, table 2.) This may not necessarily be the actual situation; therefore, the total equipment needs to produce 1.2 billion tons in 1985 should be given more consideration than any individual yearly projection.

The average output projections previously discussed do not take into consideration the potential contribution from shortwall operations. In shortwall mining, continuous-miner output averages about 50 percent greater than in room-and-pillar mining. In 1974 there were five active shortwall sections in the United States, and two more are planned for 1975.[10] These shortwall sections, however, are generally regarded as introductory to longwall mining and as such will probably not have a large, prolonged effect on continuous-miner statistics. However, shortwall mining may become popular on its own because it can solve many health and safety problems while increasing equipment output and reserve recovery rates.

Large variations in equipment output or introduction of new technology could markedly affect these projections. This is true not only for continuous miners, but for the other equipment as well, and is an inherent hazard in making any projection. Another consideration is the replacement of wornout equipment with different equipment. For example, it is projected in the cutting-machine section that replacement of wornout cutting machines by continuous miners could increase the projection of 5,705 continuous miners to 6,230.

[10] Naval Surface Weapons Center, Dahlgren Laboratory (Dahlgren, Va.). Census of U.S. Shortwall Mining Systems, October 1974. Table 9 in Self-Advancing Roof Supports for Longwall and Shortwall Mining. BuMines Contract S0144128, April 1975, 113 pp.

Longwall Mining Equipment

Longwall mining is projected to increase at a moderate rate to a total of about 30 million tons, 6 percent of total underground production, by 1985. Table 8 shows that an addition of 88 new longwall mining sections will be required between 1975 and 1985 to produce about 30 million tons per year by 1985.

TABLE 8. - Longwall statistics, 1967-85

Year	Longwall production, thousand tons	Percent of underground production	Number in use	Average output per section, thousand tons	Total needed
	(1)	(2)	(3)	(4)	(5)
1967...........	3,232	1.0	15	215.5	NAp
1968...........	4,633	1.3	22	210.6	NAp
1969...........	6,344	1.8	28	226.6	NAp
1970...........	7,132	2.1	34	209.8	NAp
1971...........	6,552	2.4	34	192.7	NAp
1972...........	7,763	2.6	40	194.1	NAp
1973...........	9,442	3.2	50	188.8	NAp
1974...........	[1] 9,000	[2] 3.0	[2] 50	[2] 180.0	NAp
1975...........	11,700	3.5	58	202.0	8
1976...........	13,945	4.0	65	214.0	8
1977...........	16,119	4.4	74	218.0	8
1978...........	18,102	4.7	82	220	8
1979...........	20,027	5.0	91	220	8
1980...........	21,757	5.3	99	220	8
1981...........	23,523	5.4	107	220	8
1982...........	25,245	5.6	115	220	8
1983...........	26,838	5.8	122	220	8
1984...........	28,474	5.8	129	220	8
1985...........	30,360	6.1	138	220	8
Total.....	NAp	NAp	NAp	NAp	88

NAp--Not applicable.
[1] Estimated owing to coal miners' strike.
[2] Estimated because data were not available.

Methodology Used

In making the longwall production projection (column 1), the same procedures were used as for developing continuous-miner production (column 1, table 7). The number in use (column 3) and the average output (column 4) were also developed by the same procedures used for continuous miners. In calculating the average output, the producing district outputs ranged from about 180,000 to 300,000 tons per year, with a nationwide weighted average of about 240,000 tons per year. The 220,000 tons per year (column 4) was a compromise between the historical output of about 200,000 and the nationwide mean.

The total needed (column 5) is simply a rational distribution of 88 new longwalls over an 11-year period.

Other Considerations

The average output for a longwall section is shown to increase by about 22 percent from 1974 to 1978. This was assumed to occur because a better understanding of the equipment will result as more mines utilize longwalls and gain experience with the proper equipment selection and use. There is also a great deal of research now being applied to longwall utilization. This research includes single-entry development, advance longwall panel mining, and introductory shortwall systems, all of which should greatly reduce longwall idle time and increase equipment efficiency. It was also felt that longwall mining must maintain a high output tonnage in order to stimulate the interest needed to be competitive and to achieve the output projected.

It was assumed, in developing table 8, that none of the longwall operations in 1974 would be lost owing to equipment deterioration. What was projected is that large inventories of parts will be kept for maintenance, and individual sections of the system will be replaced as necessary. Even if all of the operating longwalls are totally replaced by new ones, however, it will only increase equipment needs to 138.

Some of the drawbacks to longwall mining, which could preclude its wide acceptance at a rate faster than projected here, follow: (1) Oil and gas wells that penetrate the coalbed preclude longwall mining, (2) wide variation in daily production, (3) initial high capital cost, and (4) longwall idle time encountered when moving to a new panel or due to mine development delays. Longwall mining can, however, provide better surface subsidence control, safe and predictable roof falls, greater productivity, and a greater recovery of coal reserves. This type of mining holds great promise if the major problems can be satisfactorily resolved.

Cutting Machines

Projections for cutting machines needed for replacement to 1985 are shown in table 9. In 1950 about 99 percent of underground tonnage was produced by conventional methods (mainly cutting machines), compared with about 14 percent projected for 1985 (column 2). Only 825 new cutting machines (column 5) are envisioned as needed through 1985.

TABLE 9. - Cutting-machine statistics, 1950-85

Year	Cutting-machine production,[1] thousand tons	Percent of underground production	Number in use	Average output per machine, thousand tons	Total needed for replacement
	(1)	(2)	(3)	(4)	(5)
1950......	387,994	98.8	14,315	25.2	NAp
1955......	316,005	92.0	9,054	33.4	NAp
1960......	206,960	72.6	6,440	30.0	NAp
1965......	190,723	57.3	4,784	37.5	NAp
1970......	161,759	47.7	2,623	59.5	NAp
1971......	116,395	42.2	2,058	54.3	NAp
1972......	117,964	38.8	1,890	60.2	NAp
1973......	111,311	37.2	1,535	69.7	NAp
1974......	[2]112,000	[3]36.6	[3]1,600	[3]70.0	NAp
1975......	106,400	32.2	1,520	70.0	75
1976......	101,080	29.0	1,445	70.0	75
1977......	96,026	26.1	1,380	70.0	75
1978......	91,225	23.8	1,300	70.0	75
1979......	86,664	21.7	1,240	70.0	75
1980......	82,331	19.9	1,175	70.0	75
1981......	79,861	18.5	1,140	70.0	75
1982......	77,465	17.2	1,105	70.0	75
1983......	75,141	16.1	1,075	70.0	75
1984......	72,887	15.1	1,040	70.0	75
1985......	70,700	14.2	1,010	70.0	75
Total..	NAp	NAp	NAp	NAp	825

NAp--Not applicable.
[1]Includes all conventional production through 1974. From 1975 to 1985 only cutting-machine production is considered.
[2]Estimated owing to coal miners' strike.
[3]Estimated because data were not available.

Methodology Used

As previously noted, no new mines were assumed to use cutting machines for purposes of these projections. One reason for this assumption is that more men are required for cutting-machine sections than for continuous-miner sections. This has a negative effect on the productivity per man, an important industry guideline for an efficient operation. Therefore, the efficiency of the operation suffers even if the comparative equipment outputs are identical.

Cutting-machine production (column 1) is derived simply by applying the 5-percent and 3-percent production depletion factors previously mentioned.

The projections for 825 new cutting machines (column 5) presumes that machine usefulness will be prolonged as long as possible (an average of 12 instead of 10 years, for example) and that the machines then would be replaced by new machines. If this does not occur and replacement is instead by

continuous miner, the need for continuous miners could increase to about 6,230 by 1985 instead of 5,705 projected in table 7, and the number of cutting machines needed obviously decrease depending on how complete the changeover would be. (No additional projection was made for this situation.)

The average output per machine (column 4) was maintained throughout the projection period at 70,000 tons per year. It was felt that not much effort would be expended by the equipment manufacturers towards product improvement for these machines. The number in use (column 3) is derived simply by dividing column 1 by column 4.

Other Considerations

The disparity in output per man between continuous- and cutting-machine sections was aggravated by recent regulations requiring two men on some face equipment operations. Possible future requirements for two men on other face operations would further reduce the productivity of cutting-machine sections.

Mobile Loaders

The projections for mobile loaders needed for replacement to 1985 are shown in table 10. Mobile loaders can be used in both conventional and continuous sections (columns 1 and 2).

TABLE 10. - Mobile loader statistics, 1950-85

Year	Loaded in conventional sections, thousand tons	Total loaded, including continuous sections,[1] thousand tons	Percent of underground production loaded	Number in use	Total needed for replacement
	(1)	(2)	(3)	(4)	(5)
1950.....	218,126	NAp	NAp	4,228	NAp
1955.....	243,204	NAp	NAp	3,819	NAp
1960.....	162,109	NAp	NAp	2,952	NAp
1965.....	151,409	NAp	NAp	2,394	NAp
1970.....	151,375	179,185	52.3	2,420	NAp
1971.....	111,068	137,075	49.7	2,065	NAp
1972.....	114,990	148,901	49.0	1,959	NAp
1973.....	109,342	137,557	46.0	1,786	NAp
1974.....	[2]112,000	[3]140,000	[3]45.8	[3]1,800	NAp
1975.....	106,400	131,600	40.0	1,720	75
1976.....	101,080	123,480	35.4	1,625	75
1977.....	96,026	115,626	31.5	1,535	75
1978.....	91,225	108,025	28.1	1,455	75
1979.....	86,664	100,664	25.2	1,380	75
1980.....	82,331	93,531	22.6	1,320	75
1981.....	79,861	88,261	20.4	1,260	75
1982.....	77,465	83,065	18.5	1,200	75
1983.....	75,141	77,941	16.8	1,170	75
1984.....	72,887	72,887	15.1	1,135	75
1985.....	70,700	70,700	14.2	1,070	75
Total.	NAp	NAp	NAp	NAp	825

NAp--Not applicable.
[1]Assumes that no new continuous-miner sections will utilize mobile loaders.
[2]Estimated owing to coal miners' strike.
[3]Estimated because data were not available.

Methodology Used

The projections for mobile loaders as outlined in column 5 are about the same as those for cutting machines. This is not surprising since most of the mobile loaders are used in cutting-machine sections. No new continuous-miner sections were presumed to use mobile loaders, and those that currently use them would convert to other methods as this equipment wears out. Therefore the tonnages loaded (columns 1 and 2) converge in 1984, when no continuous-miner sections are projected to utilize mobile loaders.

At present, a major constraint in underground mining is efficiently moving the coal from the face to the conveyor belt. Mobile loaders, as traditionally utilized, seem to offer one more restraint to elimination of this haulage problem; therefore, they are not projected to be a major factor in new-capacity coal production.

Other Considerations

Improvements to conventional mining equipment and techniques are being developed and tested in the Bureau's Jenny mine in Martin County, Ky., via the Bureau of Mines Inherently Safe Mining System program.[11] If new methods of continuous haulage are developed that utilize mobile loaders, the assumptions made previously would no longer hold. The innovative techniques that may be forthcoming from this research could, if accepted by industry, alter many of the projections made here.

Shuttle Cars

The projections for shuttle car needs are shown in table 11. Column 4 shows a cumulative need for about 8,000 new machines by 1985.

[11] U.S. Bureau of Mines. Research 1974--A Summary of Significant Results in Mining, Metallurgy, and Energy. Special pub., 1975, pp. 75-78.

TABLE 11. - Shuttle car statistics, 1950-85

Year	Number in use	Number needed for new capacity[1]	Number needed for replacement	Total needed
	(1)	(2)	(3)	(4)
1950	3,294	NAp	NAp	NAp
1955	4,614	NAp	NAp	NAp
1960	4,958	NAp	NAp	NAp
1965	6,569	NAp	NAp	NAp
1970	6,013	NAp	NAp	NAp
1971	6,830	NAp	NAp	NAp
1972	6,623	NAp	NAp	NAp
1973	6,502	NAp	NAp	NAp
1974	[2]6,500	NAp	NAp	NAp
1975	6,470	360	325	685
1976	6,443	360	325	685
1977	6,419	360	325	685
1978	6,397	360	325	685
1979	6,377	360	325	685
1980	6,359	360	325	685
1981	6,558	327	450	777
1982	6,737	327	450	777
1983	6,898	327	450	777
1984	7,043	327	450	777
1985	7,200	327	450	777
Total	NAp	3,795	4,200	7,995

NAp--Not applicable.
[1] Based on 1/2 of the new continuous-miner sections each using 2 shuttle vehicles.
[2] Estimated because data were not available.

Methodology Used

Traditionally shuttle cars are used to move coal from the face area to the next stage of the mine transportation system. These vehicles are frequently considered uneconomical in coalbeds of 40 inches or less. Thin coalbeds, however, will probably be increasingly utilized for new mining operations. Therefore, scoops, belts, or other kinds of haulage systems will possibly be utilized in many instances in place of shuttle vehicles.

Assuming that about one-half of the new-capacity production will use shuttle vehicles, and that those wornout and discarded at ongoing operations will be replaced by new ones, we can make the projections shown in columns 2 and 3. In making these projections, consideration was also given to each shuttle vehicle being able to move 200 to 300 tons of coal per day while two of them are working in the face area.

The number in use (column 1) was determined by the same methods used to derive column 3, table 7.

Other Considerations

In developing table 11, continuation of traditional face haulage methods was assumed. Much research, however, is currently being devoted to continuous face haulage systems. These include a number of continuous-belt systems with bridge carriers and flexible or rolling corridors. Also being tested are hydraulic and pneumatic transport systems. According to Poundstone,[12] perhaps the most important research effort being conducted involves research on the continuous transportation of coal from underground mines.

If these continuous haulage systems become commercially available and broadly acceptable, the effect on underground coal transport could be swift and wide-ranging.

Conveyors--Gathering and Haulage

Gathering and haulage conveyors are being rapidly introduced to underground mines. An even greater increase is projected to 1985. Mining companies tend to prefer these belt systems because of the efficiency of operation. The conveyor systems are easily installed, maintained, and removed for replacement or relocation. New and existing underground mines will probably use these conveyors for main line haulage in place of rail haulage in most instances, and for secondary haulage in almost all instances. The projection for the number of new conveyor systems to 1985 is given in column 6, table 12.

TABLE 12. - Gathering and haulage conveyor statistics, 1950-85

Year	Number in use	Number of mines using conveyors exclusively	Average number per mine	Number needed for new capacity[1]	Number needed for replacement	Total needed
	(1)	(2)	(3)	(4)	(5)	(6)
1950........	1,013	374	2.7	NAp	NAp	NAp
1955........	1,002	314	3.2	NAp	NAp	NAp
1960........	1,566	396	4.0	NAp	NAp	NAp
1965........	2,402	553	4.3	NAp	NAp	NAp
1970........	3,012	587	5.1	NAp	NAp	NAp
1971........	3,437	540	6.4	NAp	NAp	NAp
1972........	3,776	670	5.6	NAp	NAp	NAp
1973........	3,902	687	5.7	NAp	NAp	NAp
1974........	[2]3,985	[2]687	[2]5.8	NAp	NAp	NAp
1975........	4,219	715	5.9	534	350	884
1976........	4,464	744	6.0	534	350	884
1977........	4,709	772	6.1	534	350	884
1978........	4,960	800	6.2	534	350	884
1979........	5,223	829	6.3	534	350	884
1980........	5,577	858	6.5	534	350	884
1981........	5,848	886	6.6	586	450	1,036
1982........	6,131	915	6.7	586	450	1,036
1983........	6,412	943	6.8	586	450	1,036
1984........	6,707	972	6.9	586	450	1,036
1985........	7,000	1,000	7.0	586	450	1,036
Total..	NAp	NAp	NAp	6,134	4,350	10,484

NAp--Not applicable.
[1]Assumes an average of 7 conveyor systems per mine. These include remaining 1974 mines that will add conveyor systems for expansion or replacement of other haulage.
[2]Estimated because data were not available.

[12]Poundstone, W. N. What's Needed on Research. Coal Mining and Processing, v. 12, No. 1, January 1975, pp. 54-56.

Methodology Used

In column 6 the projection is made of the need for 10,484 new conveyor systems by 1985. Some 40 percent of all existing mines currently use this system of haulage exclusively. In making the projections for column 4, it was assumed that an increasing number of existing mines and all new mines would use conveyors. The 339 new underground mines projected in table 4 will use an average of about 9 conveyors per mine. A total of 1,000 mines exclusively using conveyors at an average of 7 systems per mine (columns 2 and 3) was projected by 1985 to comply with the increasing trend towards conveyors. The number needed for replacement (column 5) was determined by assuming an average lifetime of 8 years for a conveyor system.

Other Considerations

The 1,000 mines in 1985 (column 2) will probably account for over 95 percent of underground production. This equates to an average daily load of about 300 tons per conveyor. In 1973 the average daily load was about 265 tons per day per conveyor. Utilization of the equipment is, therefore, expected to increase by about 13 percent.

The 10,484 new conveyors (column 6) will average 2,700 feet in length and will constitute about 5,300 miles of conveyor structure. The length of the 7,000 units projected to be in operation in 1985 will total about 3,600 miles. Also, some mines projected to use rail systems could change to conveyor haulage, as described in the following section.

Locomotives and Mine Cars

The assumptions made for conveyor systems suggest that locomotive use would substantially decrease in underground mines. For simplicity, the projections reported in table 13 are based only on replacement equipment needed to maintain existing capacity. It is recognized that very large mines will probably continue to use rail haulage for economic and other reasons.

TABLE 13. - Locomotive and mine car statistics, 1960-85

Year	Number of locomotives in use	Number of mine cars in use	Number of locomotives needed for replacement	Total number of mine cars needed for replacement
	(1)	(2)	(3)	(4)
1960	8,041	129,346	NAp	NAp
1965	5,063	94,424	NAp	NAp
1970	3,519	66,802	NAp	NAp
1971	3,598	55,836	NAp	NAp
1972	3,412	51,174	NAp	NAp
1973	3,276	46,790	NAp	NAp
1974	[1]3,095	[1]43,330	NAp	NAp
1975	2,910	40,740	50	700
1976	2,730	38,220	50	700
1977	2,550	35,700	50	700
1978	2,369	33,166	50	700
1979	2,190	30,660	50	700
1980	2,000	28,000	50	700
1981	1,825	25,550	50	700
1982	1,645	23,030	50	700
1983	1,460	20,440	50	700
1984	1,280	17,920	50	700
1985	1,100	15,400	50	700
Total	NAp	NAp	550	7,700

[1]Estimated because data were not available. NAp--Not applicable.

Methodology Used

The number of locomotives in use (column 1) was computed by assuming continuation of an historical average of 2.5 locomotives in those mines not using conveyors for main line haulage. A ratio of 14 mine cars per locomotive was also assumed in developing column 2. Then, assuming a 5-ton-capacity average per mine car, each 14-car train would move 70 tons of coal. Each locomotive would therefore need to average about four trips daily. Columns 3 and 4 are simply the numbers of new equipment needed for replacement for remaining 1974 capacity.

Other Considerations

Some of those mines that are projected to continue using rail systems could instead switch to conveyor haulage. If so, the need for new conveyor systems would increase by three or four for each of these small mines that converted, and the number of locomotives would drop. The introduction of rubber-tired diesel haulage may also prove to be a viable alternative to rail haulage.

Other Equipment

Much of the equipment used in underground mines has not been discussed. For example, coal scoops for face cleanup and haulage work are becoming commonplace. There are, however, few data available to base projections on; therefore, coal scoops were not evaluated. Other equipment not considered here includes rock dusters, roof bolters, fans, rubber-tired tractors and trailers, and such electrical equipment as power centers, rectifiers, and distribution centers. These are not discussed because it was felt that their availability could be increased to meet the expected demand with much less difficulty than anticipated for the equipment already considered.

Summation of New-Capacity Equipment by District

Table 14 summarizes the equipment needed for new-capacity mines by individual producing districts to 1985. These equipment requirements were determined by district needs for new production capacity, the percentage of new capacity by specific equipment type, and the historical equipment output for that type. Table 14 is in effect a compilation of new-capacity equipment needs from previous tables, reported on a district basis.

TABLE 14. - Requirements for underground mining equipment for new-capacity mines by district,[1] by 1985

Producing district[1]	Continuous miners	Longwall miners	Shuttle vehicles	Gathering and haulage conveyors
1	291	5	291	343
2	298	8	298	515
3	229	7	229	455
4	140	4	140	261
6	73	2	73	145
7	499	9	499	617
8	1,552	39	1,552	2,563
9	247	4	247	277
10	166	7	166	439
11	14	0	14	33
12	6	0	6	8
13	104	0	104	208
14	3	0	3	3
16	14	0	14	18
17	57	2	57	99
19	41	0	41	61
20	57	1	57	89
23	4	0	4	0
Total	3,795	88	3,795	6,134

[1] See appendix for list of districts.

District 8 will have the greatest amount of new-capacity production and will, therefore, require the majority of new-capacity equipment.

Potential of Equipment Manufacturers To Meet Projected Requirements

Continuous Miners

Overall, it appears that the needed continuous-mining equipment can be supplied by the manufacturers. For example, in 1974, 323 continuous miners were shipped to the domestic mining industry. The projection of 5,705 by 1985 would require a yearly average of about 519 for the 11-year period. This requires an average 61-percent increase over 1974 shipments. The increase appears to be well within industry capabilities. In fact, 1975 shipments alone are expected to be about 80 percent greater than those of 1974. Even assuming that all cutting-machine sections will be replaced by continuous miners, requiring an additional 525 miners, the resulting average yearly demand of 566 is still within manufacturing capabilities.

Delivery of a continuous miner currently takes 2 years; this could soon decrease to about 6 months, making the available supply even more certain.

Longwall Mining Sections

Currently almost all longwall equipment comes from foreign manufacturers. Domestic supply in increasing quantities, however, should be available soon. There should be little difficulty in meeting the demand for the 88, or 138, sections that were projected. There is presently less than a 1-year delivery delay for a longwall system, compared with 2 years for a continuous miner. This will also tend to enhance this equipment availability.

Gathering and Haulage Conveyors

The projections for conveyors are also well within the capabilities of the suppliers. In fact, 1975 deliveries are scheduled at about 125 per month (1,500 per year). This schedule is about 55 percent greater than the average yearly total projected in table 12. Even if all mines exclusively used conveyors by 1985, the demand could still be met by the present manufacturers.

Other Considerations

Projections for all underground equipment seem to be well within industry capabilities. All of this presupposes, of course, that enough needed materials and component parts are available. As Kroehle[13] indicates, mining machinery manufacturers can quickly expand assembly capacity but are limited in materials and component production capacity. Existing underground machinery manufacturers can produce more equipment over a several-year period than coal producers can put to work. Latest indications are that these needed materials are being made available and that the shortages experienced in 1974 are being alleviated. (Bearings for continuous miners, however, still require 1 year for delivery.)

[13]Kroehle, T. P. Coal '75: The Manufacturers' Perspective. Coal Mining and Processing, v. 12, No. 1, January 1975, pp. 45-47.

Major equipment manufacturers who are tooling up to meet the recent large-scale increase in demand are concerned as to whether this will be only a short-term business surge. If some mining companies cancel orders already placed, the manufacturers would be left with excess capacity and a stockpile of equipment. This could result from a lack of demand for certain coals (due to, for example, sulfur content) or to production cutbacks due to environmental restrictions, shortage of capital, or other considerations. Much could be done by Government policy to influence such concerns.

STRIP-MINING EQUIPMENT

A different approach was taken in making strip-mining equipment projections. The cumulative equipment bucket capacity needs for specific producing districts to 1985 was determined. A nationwide equipment output value was selected, and the number of machines needed for new-capacity mines was then calculated. After the needs for each equipment type were determined, the projections of the respective manufacturers were considered. The results of these two determinations were then compared and evaluated as to potential shortfall or adequate supply. Finally, other factors affecting equipment supply were considered.

Most of the new-capacity coal production to 1985 is projected to come from surface mines, as was shown in figure 1. To strip this coal, the overburden above it must first be removed. The method most commonly used in strip coal production is by dragline. The coal is then usually loaded by high lifts or shovels into large trucks for further disposition.

Other methods of strip mining (shovels, backhoes, bulldozers, scrapers, and front-end loaders) are utilized where the overburden is very shallow, the contour of the land is not adaptable to dragline utilization, or reclamation procedures dictate other operations. In considering new-capacity strip mining, in this report, most overburden is assumed to be removed by dragline.

Draglines

Dragline requirements for the period to 1985 are listed in table 15. These are simply the summation of district needs required to meet the new capacity that was reported in column 2, table 4.[14] (The amount of overburden rehandle has not been considered in these projections.) Districts 6 and 7 are expected to remove some overburden by methods other than dragline, as shown in column 6, table 15. This is because the contour of the land and the shallow overburden in many of these areas tend to favor methods of overburden removal other than dragline. About 99 percent of the total overburden, however, is projected to be removed by dragline. (Although some of the Western States with thin overburden and thick coal seams will probably use a truck-shovel stripping and coal-loading method, utilization of draglines will probably

[14]For example: New mines in district 1 are projected to strip 16.8 million tons per year by 1985. With a stripping ratio of 15:1, that will require removing 252 million cubic yards of overburden in 1985. Therefore, 933 cubic yards of dragline bucket capacity will be needed.

continue to be the most efficient method of operation. Therefore, the percentage of overburden removal allocated to truck-shovel operations in the Western States has not been projected.) Table 15 also shows a nationwide weighted average stripping ratio of 10:1 by 1985 (column 3). This will range from 2:1 for district 22 to 30:1 for district 14.

TABLE 15. - Requirements for dragline bucket capacity for new-capacity strip mines by district,[1] by 1985

District[1]	New strip capacity projected, thousand tons	Percent of total new strip mining	Average stripping ratio projected to 1985[2]	Total overburden to be removed, million cu yd	Overburden to be removed, million cu yd		Total dragline bucket capacity needed for new mines, cu yd[3]
					By dragline	By other than dragline	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	16,800	3.5	15	252.0	252.0	0	933
2	9,078	1.9	15	136.17	136.17	0	504
3	8,701	1.8	12	104.412	104.412	0	387
4	33,778	7.0	15	506.67	506.67	0	1,877
6	269	.1	8	2.152	0	2.152	0
7	5,415	1.1	13	70.395	46.93	23.465	174
8	54,930	11.4	14	769.02	769.02	0	2,848
9	36,588	7.6	11	402.468	402.468	0	1,491
10	34,578	7.2	16	553.248	553.248	0	2,049
11	26,007	5.4	16	416.112	416.112	0	1,541
12	862	.2	12	10.344	10.344	0	38
13	21,490	4.4	15	322.35	322.35	0	1,194
14	845	.2	30	25.35	25.35	0	94
15	47,336	9.8	13	615.368	615.368	0	2,279
17	3,089	.6	8	24.712	24.712	0	92
18	14,737	3.1	4	58.948	58.948	0	218
19	75,151	15.6	3	225.453	225.453	0	835
20	55	.0	NA	NA	0	NA	0
21	30,367	6.3	4	121.468	121.468	0	450
22	45,384	9.4	2	90.768	90.768	0	336
23	17,513	3.6	10	175.13	175.13	0	649
Total	482,973	100.2	[4]10:1	4,882.538	4,856.921	25.617	17,989

NA--Not available.
[1]See appendix for list of districts.
[2]Cubic yards of overburden removed per ton of coal mined.
[3]Based on 270,000 cu yd of overburden removed per year per cu yd of bucket capacity.
[4]Weighted average.

In deriving the projected need for 17,989 cubic yards of dragline bucket capacity by 1985 (column 7), it was assumed that every new dragline would remove 270,000 cubic yards of overburden per year per cubic yard of bucket capacity.[15] The actual figure of course will vary depending on the type of terrain, proficiency of the operator, number of operating days, degree of overburden blasting, and other factors. The mines in Appalachia might average less, while those in the Midwest and West

[15]Johnson, T. C. How Design Improvements Boost Walking Draglines Productivity. Min. Eng., v. 26, No. 10, October 1974, pp. 46-49.

might average more. The reason for using the 270,000-cubic-yard value nationwide was that, due to the scarcity of information, a current dragline output rate for each producing district could not be determined.

The total overburden to be removed (column 4) is derived simply by multiplying column 1 by column 3.

Potential of Dragline Manufacturers To Meet These Projections

To meet the increased demand for draglines, and to hold steady or shorten the current delivery delay of 5 years, the manufacturers are increasing their assembly capacities. Table 16 is a projected shipping schedule for large draglines[16] that may be the maximum attainable. The total cumulative bucket capacity scheduled is 17,760 cubic yards, based on an average bucket size of 60 cubic yards. This average is flexible and may be slightly larger or smaller depending on consumer demand. For example, a specific dragline model may be available with a bucket range of 50 to 70 cubic yards.

TABLE 16. - Large-dragline shipping schedule

Year	Number to be shipped	Cumulative bucket capacity,[1] cu yd
1975	18	1,080
1976	19	2,220
1977	21	3,480
1978	23	4,860
1979	25	6,360
1980	27	7,980
1981	29	9,720
1982	31	11,580
1983	33	13,560
1984	35	15,660
1985	35	17,760
Total	296	17,760
75 percent of total[2]	222	13,320
Minus 25 percent of 1975 schedule[2]	217	13,050

[1] Average bucket size is 60 cu yd.
[2] See text for discussion of these figures.

All of the large draglines scheduled, however, will not be available to the domestic coal industry. Some are for export and for such industries as phosphate, tar sand, and oil shale mining. The apportioned distribution to these markets is not set and will vary from year to year. Most of the capacity, however, goes to the domestic coal industry. If it is assumed that 75 percent will go to the domestic coal industry, the resulting cumulative large-dragline bucket capacity available becomes 13,320 cubic yards, as shown in table 16.

[16] Bucket capacity of large draglines is 20 cubic yards or greater. Small draglines generally have a standard 7-cubic-yard bucket.

Also of concern to the manufacturers, and to these projections, is that scheduled shipments of draglines are not being met. Shipments were about 35 percent short of schedules in 1974 and are projected to be about 25 percent short in 1975. One reason for this was the shortage of steel castings and forgings, which prevailed throughout the large-dragline industry in 1974; this shortage eased considerably in 1975, however. Another reason is the shortage of skilled labor; assembly capacity can be increased, but it will lie idle or be inefficiently utilized if the necessary skilled labor is unavailable.

Projecting how these shortages may affect future shipments is extremely difficult. Since table 16 is based on what is possibly a maximum effort, any large dragline lost because of these shortages cannot be made up in the next year's shipments, resulting in a permanent loss to cumulative bucket capacity. However, assuming that the shortages will disappear after 1975, only a 25-percent loss from 1975 schedules need be deducted, resulting in a cumulative large-dragline bucket capacity by 1985 of 13,050 cubic yards (column 3, table 16).

Table 17 reports the projections for small draglines to 1985. At present, the small-dragline manufacturers have the capacity to ship 40 to 60 pieces per year with an average bucket capacity of 7 cubic yards. The total number projected could possibly be increased, with more being shipped in the 1980's than is shown. To increase these projections would probably require a sacrifice in production of draglines smaller than 7 cubic yards, which are used predominantly in the construction industry. This schedule is, therefore, a rational evaluation of the possible demand. Most of these small draglines will be utilized in the Appalachian area and possibly in some small strip mines in the Midwest and West.

TABLE 17. - Small-dragline shipping schedule

Year	Number to be shipped	Cumulative bucket capacity,[1] cu yd
1975	50	350
1976	54	728
1977	58	1,134
1978	62	1,568
1979	66	2,030
1980	70	2,520
1981	74	3,038
1982	78	3,584
1983	82	4,158
1984	86	4,760
1985	90	5,390
Cumulative total	770	5,390

[1]Average bucket size is 7 cu yd.

The outlook for needed dragline bucket capacity to meet the PIB projections on a yearly basis shows large shortfalls through 1984. These shortages are summarized in column 5, table 18, along with the potential loss of strip production (column 6) and the resultant total strip production (column 7) that would possibly remain. After 1984, however, the dragline supply appears to be sufficient to meet the demand projected by PIB, and the total strip tonnages projected could be attained.

TABLE 18. - Dragline bucket-capacity shortfall and potential production losses

Year	Overburden for new mines, million cu yd	Cumulative bucket capacity needed for new mines, cu yd	Total cumulative bucket capacity scheduled, cu yd	Cumulative bucket capacity shipped to the domestic coal industry, cu yd	Potential yearly shortfall in total bucket capacity, cu yd	Strip production lost due to shortfall based on 10:1 stripping ratio, million tons	Resulting strip production remaining, million tons
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1975	430	1,593	1,430	890	703	19	309
1976	920	3,407	2,948	2,123	1,284	35	328
1977	1,410	5,222	4,614	3,474	1,748	47	351
1978	1,910	7,074	6,428	4,943	2,131	58	377
1979	2,410	8,926	8,390	6,530	2,396	65	408
1980	2,920	10,815	10,500	8,235	2,580	70	442
1981	3,300	12,222	12,758	10,058	2,164	58	485
1982	3,670	13,593	15,164	11,999	1,594	43	531
1983	4,060	15,037	17,718	14,058	979	26	581
1984	4,440	16,444	20,420	16,235	209	6	633
1985	4,830	17,989	23,150	18,440	0	0	672

The yearly overburden from new mines (column 1) was derived by assuming a stripping ratio of 10:1 for 1975-85 in conjunction with the new strip production reported in column 4, table 2. The cumulative bucket capacity needed for new mines (column 2) was derived by using 270,000 cubic yards of overburden removed per year per cubic yard of bucket capacity. The total cumulative bucket capacity scheduled (column 3) is the summation of column 3, table 16, and column 3, table 17. The cumulative bucket capacity shipped to the domestic coal industry (column 4) is based on availability of 75 percent of the large-dragline shipping schedule. The potential yearly shortfall in total bucket capacity (column 5) is simply the difference between columns 2 and 4.

The shortfall in coal supply described in column 6, table 18, could possibly be recovered to meet PIB projections in various other ways. With the coal price increases that would result from a supply shortage, some strip mines scheduled to close may be reconsidered as economical. Some existing strip operations may expand capacity by utilization of used or other available machinery. Likewise, the shortfall could be made up by further expansion of

the underground mining industry. Again, these alternatives are based only on meeting production needs. Any or all of them may not be viable, when considering the needed capital, men, and time that they would require. It may in fact prove impossible to supply 1.2 billion tons of coal in 1985 due to the various constraints that will be met--equipment needs notwithstanding.

It should be noted that these projections are generally very optimistic. The effect of raw material and manpower shortages are not factored into the projections after 1975, although they probably will continue to exist to some degree. The loss of equipment production due to strikes also has not been considered. This will likely have a further strong influence on 1975 shipments owing to a long strike by one of the major large-dragline manufacturers. Although these factors are not accounted for in the projections, they will probably act to constrain future dragline shipments.

Coal-Loading Shovels

Table 19 (columns 4 and 5) shows the projected requirements for coal-loading shovels for new mines for 1975-85 by individual producing district. A total need for 458 shovels with an average 12-cubic-yard bucket for new-capacity mines is shown (column 5).

By considering individual district loading equipment trends, it was assumed that about 89 percent of the new-capacity strip coal tonnage to 1985 would be loaded by shovel (column 2). The remaining 11 percent would be loaded by scrapers, bulldozers, front-end loaders, or other coal loaders (column 3).

In determining coal-loading-shovel needs to 1985, several assumptions were made because the statistical data available were not complete enough to enable district output calculations to be determined. Therefore, a nationwide average shovel output, computed from 1971-73 statistics, of 80,000 tons of coal per year per cubic yard of bucket capacity was used in deriving column 4 from column 2. This output is usually smaller in the Appalachian area and larger in the others.

It was difficult to ascertain the absolute number of new shovels that would be needed to replace wornout equipment at existing capacity mines. Based on a projected shovel life of 15 to 20 years, however, it was determined that about 200 to 300 shovels would be required for replacement. Therefore, a projection for a total of 658 to 758 new shovels can be made (footnote, column 4).

TABLE 19. - Requirements for coal-loading shovels by district,[1] by 1985

District[1]	New strip capacity projected, thousand tons	Coal to be loaded, thousand tons		Total shovel bucket capacity needed for new mines, cu yd	Number of new shovels needed at average of 12-cu-yd bucket capacity
		By shovel	By other than shovel		
	(1)	(2)	(3)	(4)	(5)
1	16,800	8,400	8,400	105	9
2	9,078	4,539	4,539	57	5
3	8,701	6,091	2,610	76	7
4	33,778	33,778	0	422	36
6	269	0	269	0	0
7	5,415	3,791	1,624	47	4
8	54,930	38,451	16,479	481	40
9	36,588	36,588	0	457	39
10	34,578	34,578	0	432	36
11	26,007	26,007	0	325	28
12	862	862	0	11	1
13	21,490	21,490	0	269	23
14	845	0	845	0	0
15	47,336	47,336	0	592	50
17	3,089	3,089	0	39	4
18	14,737	14,737	0	184	16
19	75,151	60,121	15,030	752	63
20	55	0	55	0	0
21	30,367	30,367	0	380	32
22	45,384	45,384	0	567	48
23	17,513	15,762	1,751	197	17
Total	482,973	431,371	51,602	[2]5,393	458

[1] See appendix for list of districts.
[2] This 5,393 is the total needed for new mines. Based on a 15- to 20-year life, however, it can be assumed that 200 to 300 shovels will wear out and be discarded by 1985. Therefore, the total bucket capacity needed for remaining 1974 and new mines is 7,793 to 8,993 cu yd.

Potential of Loading Shovel Manufacturers To Meet These Projections

Manufacturers of coal-loading shovels project the shipment schedule shown in table 20. The total of 9,252 cubic yards scheduled to be shipped by 1985 is large enough to meet the projected demand shown in column 4, table 19. This schedule is flexible and probably could be increased faster than shown here, if the need arises.

TABLE 20. - Coal-loading shovel shipping schedule

Year	Number to be shipped	Cumulative bucket capacity,[1] cu yd
1975	61	732
1976	62	1,476
1977	64	2,244
1978	66	3,036
1979	68	3,852
1980	70	4,692
1981	72	5,556
1982	74	6,444
1983	76	7,356
1984	78	8,292
1985	80	9,252
Cumulative total	771	9,252

[1]Average bucket size is 12 cu yd.

Comparison of table 20 with table 21 indicates that there will be no shortage of coal-loading shovels through 1985, assuming no material, manpower, or other strategic shortages occur during the projection period.

TABLE 21. - Annual coal-loading shovel needs to 1985

Year	Coal tonnage from new mines, thousand tons	Tonnage by loading shovel, thousand tons	Cumulative bucket capacity needed, cu yd
1975	43,050	38,315	479
1976	92,060	81,933	1,024
1977	140,783	125,297	1,566
1978	190,768	169,784	2,122
1979	240,426	213,979	2,675
1980	291,523	259,455	3,243
1981	329,089	292,889	3,661
1982	366,856	326,502	4,081
1983	405,931	361,279	4,516
1984	444,169	395,310	4,941
1985	482,973	431,371	5,393

Other Equipment

An evaluation of off-the-road truck availability can give an indication of what can be expected for much of the other equipment used in strip mining. Shortages of component parts such as transmissions and differential gears, together with declining foundry capacity and consequent shortages in gray steel and high-alloy steel, plagued manufacturers throughout the first half of the 1970's. Production could have been increased at least 15 to 20 percent if

materials had been available in adequate supply. Most manufacturers have been increasing their capacity in anticipation of an increase in material supply, and an even greater demand for equipment. Manufacturers are quoting delivery delays of from 90 days to 1 year depending on truck size. As noted, most of this observation can be applied to other mining equipment such as scrapers, bulldozers, and front-end loaders.

About 30 percent, or some 450, of the under-70-ton off-the-road trucks produced went to the coal-mining industry in 1974. In the first half of 1975, about 70 percent of production, some 500 trucks, went to the coal-mining industry. This higher percentage can be attributed to a decrease in demand by the construction industry because of economic conditions coupled with orders from the coal industry for the smaller, more readily available sizes because of the long delivery delays for trucks larger than 70 tons. It is possible that three times the number of 75- to 85-ton trucks could be sold than are currently produced. Coal-mining-industry requirements for under-70-ton trucks should return to about 30 percent of production in the near future. About 50 percent of production of trucks larger than 70 tons goes to the coal-mining industry (about 150 trucks in 1974 and 200 in 1975). According to manufacturers' projections, this percentage should be maintained through 1980.

Assuming that these figures hold, about 30,000 tons of new truck capacity will be added to the coal-mining industry each year. With an average value of 75 percent for truck availability, this should be adequate to meet the demands of the new strip mines for coal hauling, overburden handling, backfilling, and reclamation. It will also provide needed replacements for those trucks that are discarded after the average useful lifetime of about 8 years, and will also be adequate to meet the surface haulage demands of the underground mining industry.

Off-the-road truck manufacturers feel that they can meet the present and future demands of the coal-mining industry with moderate increases in assembly capacity, provided that the materials of fabrication are available.

Stripping shovels were not considered in these projections because they are limited in depth of cut and therefore cannot be utilized as universally as draglines. The last one was commissioned for use in 1971, none were shipped in 1972, 1973, or 1974, and none were scheduled for 1975. For these reasons, no new stripping shovels are projected for use to 1985.

Bucket-wheel excavators have met with limited success in overburden removal operations in this country, although they can be more efficiently utilized in reclamation and possibly even in some coal-loading operations. Their use in overburden removal to 1985, however, is not considered in these projections.

These projections also assume that an adequate supply of AN-FO or similar blasting products will be available to the coal-mining industry. A study by

Forecasting International, Ltd.,[17] states that coal mines must be accorded high-priority access to supplies of AN-FO, perhaps including some form of Government-guaranteed supplies.

As with underground mining, there remains much equipment that has not been considered. In some cases, the reasons are because data are not sufficient or readily available to determine trends, projections, utilization rates, or other factors. In others, it was felt that the equipment could be delivered to meet the expected needs easily and therefore need not be evaluated.

NEED FOR RESEARCH AND DEVELOPMENT

This study points up the need for and value of additional coal-mining research and development. The decline in machine productivity reflected by tables 7 (column 4) and 8 (column 4) over the last 5 years is mirrored by an even more severe decline in productivity per man-shift over the same period. The combination of decreased output per dollar of labor cost and decreased output per dollar of equipment cost has added to the upward spiral in the price of coal. A review of the production per machine-year statistics from tables 7 and 8 also suggest that a 20-percent increase in machine productivity is within the capability of today's equipment. This is probably an understatement of potential since those production figures were set by an earlier generation of machine when theoretical production capabilities were far less than for today's equipment. In most cases the theoretical production figures of today's machine systems are at least an order of magnitude greater than the production actually being realized. This unused capability represents an opportunity for innovative research to help assure the technology to meet national energy goals.

For the purpose of this study, it has been assumed that machine productivity in underground mines will increase slightly for both continuous and longwall sections and then stabilize at this level through 1985. However, there is no <u>necessary</u> reason why this should occur, and in the absence of a sound research, development, and demonstration program, machine productivity might stabilize at today's levels or even continue to shift lower.

A similar situation exists in the surface-mining area. Many States have enacted more stringent surface-mining reclamation requirements, and Federal legislation has been proposed. To the extent to which inefficient extraction and reclamation technologies are employed to meet present and future reclamation requirements, man and machine productivities will fall. A productive and comprehensive research and development effort to develop improved surface-mining technology will help minimize this inefficiency and reduce labor and equipment requirements.

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[17] Forecasting International, Ltd. Technological Forecast of the Coal Extraction Process--Summary Report. BuMines Contract 50241069, Oct. 7, 1974, pp. 1-67.

CONCLUSIONS

Overall, it appears that the coal-mining equipment needed to meet the PIB projection of 1.2 billion tons of coal in 1985 can be made available by the manufacturers, but a dragline shortfall in the interim years is possible.

Material shortages for the manufacturers eased considerably in the first quarter of 1975, although manpower shortages still plague the dragline industry. The delivery delay for draglines is 5 years, but should drop from the current 2 years for continuous miners.

Underground equipment manufacturers can meet or better the equipment needs projected here on a year-to-year, or long-term, basis. Underground equipment could be made available faster than the mining companies could utilize it.

APPENDIX.--DESCRIPTION OF BITUMINOUS COAL AND LIGNITE PRODUCING DISTRICTS

DISTRICT 1.—EASTERN PENNSYLVANIA

Pennsylvania

Armstrong County (part).—All mines east of Allegheny River, and those mines served by the Pittsburgh & Shawmut Railroad located on the west bank of the river.

Fayette County (part).—All mines located on and east of the line of Indian Creek Valley branch of the Baltimore & Ohio Railroad.

Indiana County (part).—All mines not served by the Saltsburg branch of the Pennsylvania Railroad.

Westmoreland County (part).—All mines served by the Pennsylvania Railroad from Torrance, east.

All mines in the following counties:

Bedford	Centre	Forest	McKean
Blair	Clarion	Fulton	Mifflin
Bradford	Clearfield	Huntingdon	Potter
Cambria	Clinton	Jefferson	Somerset
Cameron	Elk	Lycoming	Tioga

Maryland.—All mines in the State.

West Virginia.—All mines in the following counties:

Grant	Mineral	Tucker

DISTRICT 2.—WESTERN PENNSYLVANIA

Pennsylvania

Armstrong County (part).—All mines west of the Allegheny River except those mines served by the Pittsburgh & Shawmut Railroad.

Fayette County (part).—All mines except those on and east of the line of Indian Creek Valley branch of the Baltimore & Ohio Railroad.

Indiana County (part).—All mines served by the Saltsburg branch of the Pennsylvania Railroad.

Westmoreland County (part).—All mines except those served by the Pennsylvania Railroad from Torrance, east.

All mines in the following counties:

Allegheny	Butlar	Lawrence	Venango
Beaver	Greena	Mercer	Washington

DISTRICT 3.—NORTHERN WEST VIRGINIA

West Virginia

Nicholas County (part).—All mines served by or north of the Baltimore & Ohio Railroad.

All mines in the following counties:

Barbour	Jackson	Randolph	Webster
Braxton	Lewis	Ritchie	Wetzel
Calhoun	Marion	Roane	Wirt
Doddridge	Monongalia	Taylor	Wood
Gilmer	Pleasants	Tylar	
Harrison	Preston	Upshur	

DISTRICT 4.—OHIO.—All mines in the State.

DISTRICT 5.—MICHIGAN.—All mines in the State.

DISTRICT 6.—PANHANDLE

West Virginia.—All mines in the following counties:

Brooke	Hancock	Marshall	Ohio

DISTRICT 7.—SOUTHERN NO. 1

West Virginia

Fayette County (part).—All mines east of Gauley River and all mines served by the Gauley River branch of the Chesapeake & Ohio Railroad and mines served by the Virginian Railway.

McDowell County (part).—All mines in that portion of the county served by the Dry Fork branch of the Norfolk & Western Railroad and east thereof.

Raleigh County (part).—All mines except those on the Coal River branch of the Chesapeake & Ohio Railroad and north thereof.

DISTRICT 7.—SOUTHERN NO. 1 (Continued)

Wyoming County (part).—All mines in that portion served by the Gilbert branch of the Virginian Railway lying east of the mouth of Skin Fork of Guyandot River and in that portion served by the main line and the Glen Rogers branch of the Virginian Railway

All mines in the following counties:

Greenbrier	Mercer	Monroe	Pocahontas	Summers

Virginia

Buchanan County (part).—All mines in that portion of the county served by the Richlands-Jewell Ridge branch of the Norfolk & Western Railroad and in that portion on the headwaters of Dismal Creek east of Lynn Camp Creek (a tributary of Dismal Creek).

Tazewell County (part).—All mines in those portions of the county served by the Dry Fork branch to Cedar Bluff and from Bluestone Junction to Boissevain branch of the Norfolk & Western Railroad and Richlands-Jewell Ridge branch of the Norfolk & Western Railroad.

All mines in the following counties:

Montgomery	Pulaski	Wythe	Giles	Craig

DISTRICT 8.—SOUTHERN NO. 2

West Virginia

Fayette County (part).—All mines west of the Gauley River except mines served by the Gauley River branch of the Chesapeake & Ohio Railroad.

McDowell County (part).—All mines west of and not served by the Dry Fork branch of the Norfolk & Western Railroad.

Nicholas County (part).—All minas in that part of the county south of and not sarved by the Baltimore & Ohio Railroad.

Raleigh County (part).—All mines on the Coal River branch of the Chesapeake & Ohio Railroad and north thereof.

Wyoming County (part).—All mines in that portion served by the Gilbert branch of the Virginian Railway and lying west of the mouth of Skin Fork of Guyandot River.

All mines in the following counties:

Boone	Kanawha	Mason	Wayne
Cabell	Lincoln	Mingo	
Clay	Logan	Putnam	

Virginia

Buchanan County (part).—All mines in the county, except in that portion on the headwaters of Dismal Creek, east of Lynn Camp Creek (a tributary of Dismal Creek) and in that portion served by the Richlands-Jewell Ridge branch of the Norfolk & Western Railroad.

Tazewell County (part).—All mines in the county except in those portions served by the Dry Fork branch of the Norfolk & Western Railroad and branch from Bluestone Junction to Boissevain of Norfolk & Western Railroad and Richlands-Jewell Ridge branch of the Norfolk & Western Railroad.

All mines in the following counties:

Dickinson	Russell	Wise
Lee	Scott	

Kentucky.—All mines in the following counties in eastern Kentucky:

Bell	Greenup	Lawrence	Morgan
Boyd	Harlan	Lee	Owsley
Breathitt	Jackson	Leslia	Perry
Carter	Johnson	Letcher	Pike
Clay	Knott	McCreary	Rockcastle
Elliott	Knox	Magoffin	Wayne
Floyd	Laurel	Martin	Whitley

Tennessee.—All mines in the following counties:

Anderson	Cumberland	Overton
Campbell	Fentress	Roane
Claiborne	Morgan	Scott

North Carolina.—All mines in the State.

DISTRICT 9.—WEST KENTUCKY

Kentucky.—All mines in the following counties in western Kentucky:

Butler	Hancock	McLean	Todd
Christian	Henderson	Muhlenberg	Union
Crittenden	Hopkins	Ohio	Warran
Daviess	Logan	Simpson	Webster

DISTRICT 10.—ILLINOIS.—All mines in the State.

DISTRICT 11.—INDIANA.—All mines in the State.

DISTRICT 12.—IOWA.—All mines in the State.

DISTRICT 13.—SOUTHEASTERN

Alabama.—All mines in the State.

Georgia.—All mines in the following counties:

Dade	Walker

Tennessee.—All mines in the following counties:

Bledsoe	Marion	Sequatchie	White
Grundy	McMinn	Van Buren	
Hamilton	Rhea	Warren	

DISTRICT 14.—ARKANSAS-OKLAHOMA

Arkansas.—All mines in the State.

Oklahoma.—All mines in tha following counties:

Haskell	Le Flore	Sequoyah

DISTRICT 15.—SOUTHWESTERN

Kansas.—All mines in the State.

Texas.—All mines in the State.

Missouri.—All mines in the State.

Oklahoma.—All mines in the following counties:

Coal	Latimer	Okmulgee	Rogers	Wagoner
Craig	Muskogee	Pittsburg	Tulsa	

DISTRICT 16.—NORTHERN COLORADO

All mines in the following counties:

Adams	Douglas	Jackson	Larimer
Arapahoe	Elbert	Jefferson	Weld
Boulder	El Paso		

DISTRICT 17.—SOUTHERN COLORADO

Colorado.—All mines except those included in District 16.

New Mexico.—All mines except those included in District 18

DISTRICT 18.—NEW MEXICO

New Mexico.—All mines in tha following counties:

Grant	McKinley	Sandoval	San Miguel	Socorro
Lincoln	Rio Arriba	San Juan	Santa Fe	

Arizona.—All mines in the State.

California.—All mines in tha State.

DISTRICT 19.—WYOMING

Wyoming.—All mines in the State.

Idaho.—All mines in tha State.

DISTRICT 20.—UTAH.—All mines in the State.

DISTRICT 21.—NORTH DAKOTA-SOUTH DAKOTA.

All mines in North Dakota and South Dakota.

DISTRICT 22.—MONTANA.—All mines in the State.

DISTRICT 23.—WASHINGTON

Washington.—All mines in the State.
Oregon.—All mines in the State.
Alaska.—All mines in the State.

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